Design of a Railroad Viaduct for The Overton County (Tenn.) Railroad

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DESIGN OF A RAILROAD VIADUCT

for

THE OVERTON COUNTY RAILROAD

A THESIS

Presented by

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DESIGN OF A STEEL RAILROAD VIADUCT.

This viaduct is designed for the Overton County RR., and is used in crossing the Obie River in Overton County, Tennessee.

The design of this structure, and the estimate of its cost may be divided into four parts: 1. Selection of design. 2. Determination of stresses. 3. Calculation of sections and weights. 4. Cost.

1. The design submitted in this thesis was chosen on account of the accuracy with which the stresses could be determined. In this design the horizontal struts make it possible to calculate the diagonals for tension only. If these struts are omitted it is necessary to design the diagonals for alternate stresses, that is, for tension and compression. This, on account of the extreme length of the members, must be avoided as it greatly increases the cross section and consequently the weight. The design in which the diagonals are omitted gives rise to indeterminate stresses, and also to an excessive bending moment in the columns.

2. The loading used in determining the stresses was according to Cooper's Class E50, with the exception that the two locomotives were followed by a uniform load of 7000# per foot of track instead of 5000# per foot of track.

The reaction on the girders was figured analytically, and the stresses in the towers were determined graphically.

In determining the dead load stress in any one member in the towers the weight of the piece itself was not considere as producing any stress in that member, but this weight was considered in determining the dead load stress in the members in the lower panels.

3. The unit stresses were figured according to Cooper's Specifications for Railroad Bridges, Class E50.

In estimating the weight of this structure it was necessary to make some allowance for the weight of the connection plates. This was done by considering that each horizontal member extended from center to center of column, and that the diagonal members extended from one of these intersecting points to the corresponding point on the other post on the lower panel. This always added from two to six feet to the length of the member, thereby balancing the weight of the connection plates.

4. The cost of the steel erected will vary between $80 and $95 per ton. The value of $85 was taken as the most probable price under existing conditions. The cost of concrete in place was taken at $5.20 per cubic yard. It was not possible to make an estimate of the cost of excavation for the piers owing to the lack of information concerning the nature of the soil in this vicinity.

Design of 77'-6" Deck Plate Girder Span.

Depth of girder (back to back of angles) = 7'-0"

Girders are spaced 8'-0" center to center.

Outer guard timbers 6"x8" laid flat and parallel to the track rails, and notched one inch over every cross tie. They are spliced over a tie by a lap joint 6" long, a bolt being passed through the splice so as to secure the ends of both timbers to the tie.

Assume the weight of track at 450# per linear foot, and that one tie will carry a length of track of 1'-3". The cross tie then acts as a beam whose supports are 96" apart, carrying two equal and symmetrically placed concentrated loads 59-1/2" apart, each of which is 10280#. Allowable unit stress, impact not considered, 1000# per sq. in.

Bending Moment = 10280 x 19.5 = 200460 in. lbs.

$200460 = 1000bd^2/6$, whence $bd^2 = 1202$

Let the safe bearing on the side of the fiber be taken at 250# per square inch. The bearing area required is then

10280/250 = 41.1 sq.ins.

If the width of the base of rail is 6" then the bredth of the timber must be at least 7". We will use 8" as it is the nearest commercial width of timber.

$d^2 = 1202/8 = 150$

d = 12.2" or 13"

WEB SECTION

Maximum live load shear = 146040#

Assume the weight of one girder at 45000#

The weight of track, at 235# per ft., is 77.5 x 235=18213

The total dead loadshear = (45000 + 18200)/2 = 31600#

Net area of web section required = 177640/10000 = 17.76

A plate 84"x3/8" has a gross area of 31.5 sq. ins.

31.5 sq.ins. - 17.76 sq. ins. = 13.74 sq.ins. which allows for 36 rivits on one gage line.

BENDING MOMENT AT DIFFERENT SECTIONS.

Bending moment given in kips.

Sections	7.00'	14.00'	21.00'	28.00'	35.00'	38.75'
L.L.	864.3	1557.2	1921.3	2428.4	2606.7	2631.1
D.L.	198.4	362.5	483.9	565.3	607.0	613.0
Total	1062.7	1919.7	2405.2	2993.7	3213.7	3244.1

For bending moment a uniform live load of 7000# per foot of track was used.

SHEAR AT DIFFERENT SECTIONS.

Section	0.00	7.00	14.00	21.00	28.00	35.00
L.L.	135625	111125	91123	72179	55440	40757
D.L.	31620	25908	20196	14484	8272	3060
Total	167245	137033	111319	86663	64212	43817
Effective depth.	81.16	81.18	82.48	83.34	83.34	83.34

FLANGE AREA AND LENGTH OF COVER PLATES.

7.oo ft. section.

Assume an effective depth of 84" - (2 x 2.25") = 79.5"

A = M/Sh = (1062.7x12x1000)/(10000x79.5) = 16.02 sq.ins.net.

Section composed of 2 angles 8"x8"x3/4" and 1 plate 18"x5/8".

14.00 ft. section.

A = (1919.7 x 12 x 1000)/(10000 x 79.5) = 28.95 sq. ins. net.

Section composed of 2 angles 8"x8"x3/4" and 1 plate 18"x5/8".

21.00 ft. section.

A = 2405.2 x 12 x 1000)/(10000 x 83) = 34.77 sq. ins. net.

Section composed of 2 angles 8"x8"x3/4" and 2 plates 18"x5/8"

NOTE:- Plate 18"x5/8" starts 14'-0" from end of girder.(2'-0" being allowed for splice.)

28.00 ft. section.

A = (2993.7 x 12 x 1000) / (10000 x 84) = 42.77 sq. ins. net.

Section composed of 2 angles 8"x8"x3/4" and 2 plates 18"x5/8" and plate 18"x1/2". NOTE:- 18"x1/2" plate starts 25'-0" from end of girder.

35.00 ft. section.

A = (3213.7 x 12 x 1000)/(10000 x 84) = 45.62 sq. ins. net.

Section composed of the same size material as is used in the 28.00 ft. section.

38.75 ft. section.

A = 3244.1 x 12 x 1000)/ (10000 x 84) = 46.35 sq. ins. net.

Section composed of the same size material as is used in the 28.00 ft. section.

STIFFENERS.

Allowable unit stress = P = 10000 - 45(1/r)

If we use two angles 6"x3-1/2"x3/8" as stiffeners we have a gross area of 6.84 sq.ins. The allowable load will be

8055 x 6.84 = 55100#

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THEORETIC RIVET PITCH IN FLANGES.

Pitch at 0.00' section.

167245/81.16 = 2060#

The live load weight on one rail is one wheel (25000#) distributed over three ties (42"). The corresponding weight of track supported by one girder is 700#, making a total weight of 25700# over 42", or 612# per linear inch.

The resultant of 2060# and 612# is 2150#.

The value of a 7/8" rivet in bearing on a 3/8" plate, at 15000# per sq.in., is 4920#. The required pitch is

4920/2150 = 2.288".

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Pitch at 7.00' section.

137033/81.16 = 1688#

Resultant of 1688# and 612# is 1805#.

Required pitch = 4920/1800 = 2.73"

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Pitch at 14.00' section.

111319/81.16 = 1374#

Resultant of 1374 and 612 is 1504#.

4920/1504 = 3.26"

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Pitch at 21.00' section.

86063/82.48 = 1050#

Resultant of 1050# and 612 is 1215#

4920/1215 = 4.05"

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Pitch at 28.00' section.

64212/83.34 = 772#

Resultant of 772# and 612# is 985#.

4920/985 = 5.00".

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Pitch at 35.00' section.

43817/83.34 = 527#

Resultant of 527# and 612# is 807#.

4920/807 = 6.11"

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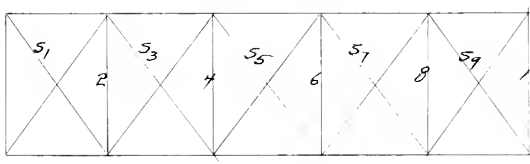
LATERAL BRACING.



Wind load = 600# per linear foot of span.

Wind load per panel = 600 x 7.75 = 4650#

Reaction = (600 x 77.5)/2 = 20925#

Stress in #2 - 4 - 6 - 8 - 10 = -4650#

S_1 = 20925 x 1.392 = 29128#

S_2 = 16275 x 1.392 = 22655#

$S_5 = 11625 \times 1.392 = 16182$#

$S_7 = 6975 \times 1.392 = 9710$#

$S_9 = 2325 \times 1.392 = 3296$#

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Stress in S_1 is 29128#.

Allowable unit stress is 12000# or $-P = 13000 - 60L/r$

L is about 113". P = 13000 - 5700 = 7300# per sq. in.

29128/7300 = 3.99 sq.ins. required.

Use one angle 6"x6"x3/8" which has an area of 4.36 sq. ins.

All intermediate substruts and horizontal members of intermediate cross frames are composed of one angle 6"x6"x3/8".

Diagonals of cross frames are composed of one angle 3-1/2"x3-1/2"x3/8".

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END CROSS FRAME.

Compressive stress in horizontal member = -22500#

Tensile stress in diagonal member = 23400#

Horizontal member composed of 2 angles 5"x3-1/2"x7/16"

Diagonal member composed of one angle 3-1/2"x3-1/2"x3/8"

ESTIMATE OF WEIGHT OF 77'-6" DECK GIRDER.

				Weight.	
	FLANGES				
4	Angles	8"x8"x3/4"x	38'-9"	6029	
2	Cov.Plt.	18"x5/8"x	40'-0"	3060	
2	Cov.Plts.	18"x5/8"x	26'-0"	1990	
2	Cov.Plts.	18"x1/2"x	15'-0"	918	
				12007	12007
	FLANGE SPLICES.				
2	Angles	7"x7"x9/16"x	3'-6"	184	
2	Plts.	7"x9/16"x	3'-6"	92	
				276	276
	WEB				
1	Web Plt.	84"x3/8"x	40'-0"	4285	4285
	WEB SPLICE				
3	Plts.	13"x7/16"x	5'-8"	329	329
	STIFFENERS.				
21	Angles	6"x3-1/2"x3/8"x7'-0"		1720	
3	Fill Plts.	3-1/2"x3/4"x	5'-8"	152	
2	" "	3-1/2"x5/16"x	5'-8"	42	
				1914	1914
					18811
	ONE-HALF OF UPPER LATERAL SYSTEM.				
5	Angles	6"x6"x3/8"x	9'-6"	708	
2-1/2	"	6"x4"x3/8"x	6'-9"	208	
10	"	6"x4"x3/8"x	0'-6"	62	
1	Plt.	12"x3/8"x	22'-6"	344	
				1422	
	ONE-HALF OF LOWER LATERAL SYSTEM.				
5	Angles	6"x6"x3/8"x	9'-6"	708	
4	"	6"x4"x3/8"x	0'-6"	25	
1	Plt.	12"x3/8"x	14'-0"	214	
				947	

END CROSS FRAME

				Weight.
4	Angles	5"x3-1/2"x7/16"x	6'-6"	312
2	"	3-1/2"x3-1/2"x3/8"x9'-3"		157
1	Plate	12"x3/8"x	10'-0"	153
				622

INTERMEDIATE CROSS FRAME.

2	Angles	6"x4"x3/8"x	6'-6"	160
2	"	3-1/2"x3-1/2"x3/8"x9'-3"		157
1	Plate	12"x3/8"x	5'-0"	77
				394

WEIGHT OF ONE GIRDER COMPLETE

1	Girder	37622
1/2	Upper Lateral System	1422
1/2	Lower " "	947
1	End Cross Frame	622
2	Intermediate Cross Frame	788
		41401
	3% for rivet heads	1242
		42643
	77.5' of track at 22#	17440
	Total weight	60083#

DESIGN OF 38'-6" DECK PLATE GIRDER SPAN.

Depth of girder (back to back of angles) = 7'-0"

Girders spaced 8'-0" center to center

CROSS TIES

Cross ties are the same as those used on the 77'-6" girder.

WEB SECTION.

Maximum live load shear = 92200#

Assume the weight of one girder at 28000#. The weight of track at 235# per linear foot = 38.5 x 235 = 9050#.

Total dead load shear = 28000/2 + 9050/2 = 18525#

Total vertical shear = 92200# + 18525# = 110725#

The required net area = 110725/10000 = 11.07 sq.ins.

A plate 84"x3/8" has 31.5 sq. ins. of metal.

31.5 - 11.07 = 20.43 sq.ins. which allows for 55 rivets on one gage line.

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FLANGES

Since the flange section is to be composed of two angles, it is only necessary to find the bending moment at the center.

Bending moment at the center = 658 kip feet.

A = M/Sh = (658 x 12 x 1000)/(10000 x 80.5) = 9.81 sq. ins.

We will use 2 angles 6"x6"x5/8" which have an area of 14.22 square inches.

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STIFFENERS.

F = 10000 - 45L/r   Assume 2 angles 5"x3-1/2"x3/8"

r = 1.6   L = 84   45L/r = 2365

Area of 2 angles 5"x3-1/2"x3/8" is 6.10 sq. ins.

Allowable load = 7635 x 6.10 = 46575#

SHEAR AT DIFFERENT SECTIONS.

Section	0.00'	5.00'	10.00'	15.00'	19.25'
L.L.	92200	73400	56400	41500	30600
D.L.	18525	13715	8905	4095	0
Total	110725	87115	65305	45595	30[illegible]

Effective depth for all sections is 80.5 inches.

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THEORETIC RIVET PITCH IN FLANGES.

Pitch at 0.00' section.

110725/80.5 = 1375#

Resultant of 1375# and 612# is 1505#

Required pitch = 4920/1505 = 3.28"

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Pitch at 5.00' section.

87115/80.5 = 1082#

Resultant of 1082# and 612# is 1243#

Required pitch = 4920/1243 = 3.95"

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Pitch at 10.00' section.

65305/80.5 = 811#

Resultant of 811# and 612# is 1016#

Required pitch = 4920/1016 = 4.84"

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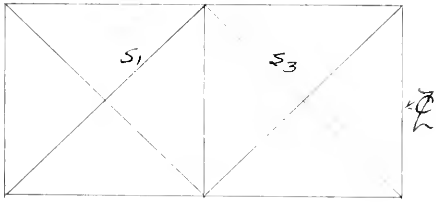
Pitch at 15.00' section.

45595/80.5 = 566#

Resultant of 566# and 612# is 834#

Required pitch = 4920/834 = 5.90"

LATERAL BRACING.



Wind load = 600# per linear foot of span.

Wind load per panel = 600 x 9.625 = 5775#

Reaction = (600 x [illegible])/2 = 8666#

Stress in #2 and #4 is -5775#

S_1 = 5775 x 1.5644 = 9034#

S_3 = 2888 x 1.5644 = 4518#

Since the ratio of l/r must not exceed [illegible], we [illegible] use an angle [illegible]"x4"x3/8". All intermediate [illegible] and horizontal members of intermediate cross frames are [illegible] of [illegible] angle [illegible]. [illegible] diagonals of [illegible] cross frames are composed of one angle 3-1/2"x3-1/2"x3/8".

END CROSS FRAME.

Compressive stress in horizontal member = -9300#

Tensile stress in diagonal member = 9400#

Horizontal member composed of two angles 5"x3-1/2"x3/8"

Diagonal member composed of one angle 3-1/2"x3-1/2"x3/8"

ESTIMATE OF WEIGHT OF 38'-6" DECK GIRDER.

FLANGES.

4	Angles	6"x6"x5/8"x	38'-6"	9317

WEB.

1	Plate	84"x3/8"x	38'-6"	4124

STIFFENERS.

16	Angles	5"x3-1/2"x3/8"x	7'-0"	1165
3	Fillers	3-1/2"x5/8"x	5'-8"	126
				14732#

ONE HALF OF UPPER LATERAL SYSTEM.

2	Angles	6"x6"x3/8"x	9'-6"	283
1	"	6"x4"x3/8"x	6'-9"	83
4	"	6"x4"x3/8"x	0'-6"	25
1	Plate	12"x3/8"x	12'-0"	184
				575#

ONE HALF LOWER LATERAL SYSTEM.

2	Angles	6"x6"x3/8"x	9'-6"	283
4	"	6"x4"x3/8"x	0'-6"	25
1	Plate	12"x3/8"x	8'-0"	122
				430#

END CROSS FRAME.

4	Angles	5"x3-1/2"x3/8"x	6'-6"	270
2	"	3-1/2"x3-1/2"x3/8"x	9'-3"	157
1	Plate	12"x3/8"x	10'-0"	153
				580#

INTERMEDIATE CROSS FRAME.

2	Angles	6"x4"x3/8"x	6'-6"	160
2	"	3-1/2"x3-1/2"x3/8"x	9'-3"	157
1	Plate	12"x3/8"x	5'-0"	77
				394#

WEIGHT OF ONE GIRDER COMPLETE.

1	Girder	14732
1/2	Upper Lateral System	575
1/2	Lower Lateral System	430
1	End Cross Frame	580
1	Intermediate Cross Frame	394
		16711
	3% for rivet heads	501
		17212
	38.5 feet of track at 225# per ft.	8663
	Total	25875#

DESIGN OF TOWERS.

Maximum concentration per bent is 121000# + 92150 = 213150#

Maximun traction load = 116 x3500 x 20% = 81200#

L. L. wind load = 450# per foot 6ft. above base of rail

= 450 x (38.5 + 77.5)/2 = 450 x 58 = 26100#

L. L. wind load at base of rail = 150 x 58 = 8700#

D. L. wind load at center line of girder = 500 x 58 = 29000#

D. L. wind load for 32ft. panel (vertical) = 32 x 200 = 6400#

L. L. wind load for 32ft. panel (vertical) = 32 x 100 = 3200#

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TOWER # (1-2) .

Stress = -81200# in members AB - CD - EF - GH.

P = 13000 - 60L/r = 13000 - 4860 = 8140#

Allowed unit pressure for live load is 2/3 of 8140 or 5425#

81200/5425 = 14.94 sq. ins.

In order to prevent undue saging of the member due to its length we will use two channels 15" -33#, laced.

Estimated weight of one piece.

2	Channels 15"-33#		38'-0"	2508
4	Batt. Plt . 17"x3/8"x		2'-0"	195
1	Lac. Bar	2-1/2"x3/8"x	280'-0"	895
				3598
	Rivet Heads 2-1/2%			90
				3688#

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MEMBERS BC - AD - CF - FG - EH.

Stress = 106000#

Required area = 106000/12000 = 8.83 sq. ins.

Two channels 12"-25# have a gross area of 14.70 sq. ins.

14.70 - 4.25 = 10.45 sq. ins. = net area available.

Estimated weight of one member.

2	Channels 12"-25#	49'-3"	2463
6	Batt .Pt. 18"x3/8" x	2'-0"	275
1	Lac.Bar 2-1/2"x3/8"x	200'-0"	638
			3376#
	Rivet Heads 2-1/2%		82
			3458#

Member GK.

Stress = 65000#, equivalent stress = 117000#.

Required area = 117000/6110 = 19.14 sq. ins.

Two channels 15"-33# have a gross area of 19.30 sq. Ins.

Estimated weight of member.

2	Channels 15"-33#	60'-0"	3960
8	Batt.Pl. 18"x3/8"x	2'-0"	367
1	Lac.Bar 2-1/2"x3/8"x	175'-0"	558
			4885
	Rivet heads 2-1/2%		122
			5007#

Member #(1-2)

Stress = -80000# Length = 8'-0"

Required area = 80000/7700 = 10.39 Sq. Ins.

Two channels 10"-20# have a gross area of 11.76 sq. Ins.

Estimated weight of member.

2	Channels 10"-20#	8'-0"	320
4	Batt. Pl. 18"x3/8"x	2'-0"	184
1	Lac. Bar 2-1/2"x3/8"x	25'-0"	80
			584
	Rivet Heads 2-1/2%		15
			599#

Members #(1-4) and #(2-3)

Stress = 34000#

Required area = 34000/12000 = 2.83 sq. ins. net.

Two angles 3-1/2"x3-1/2"x3/8" have a gross area of 4.96 sq. ins., and a net area of 4.21 sq. ins.

Estimated weight of one member.

2	Angeles 3-1/2"x3-1/2"x3/8"x	35'-0"	595
2	Batt. Pl. 18"x3/8"x	2'-0"	92
1	Lac. Bar 2-1/2"x3/8"x	40'-0"	128
			816
	Rivet Heads 2-1/2%		21
			836#

Member AC - Bd - (1-3) - (2-4).

Estimated dead load on AC

(1-4)	836
1/2(1-2)	300
CB	3353
1/2 (AB)	1844
From girders and track	42980
	49313#

Total stress in member = -308000#

Assume a section composed of four angles 6"x6"x3/4" and two plates 24"x5/8". This section has a gross area of 63.76 sq. ins.

r = 5.77   P = 9000 - 6340# per sq. ins.

Required area = 308000/6340 = 48.58 sq. Ins.

Estimated weight of member.

4	Angles	6"x6"x3/4"x	32'-0"	3674
2	Plates	24"x5/8"x	32'-0"	3264
				6938
	Rivet Heads 3%			208
				7146#

Members (3-4), (5-6), (7-8(, and (9-10).

Stress = -11000#

Assume the maximum unsupported length to be 30'-0", and the radius of gyration to be 2.6.

Required area = 11000/4600 = 2.40 sq. ins.

Use two channels 7" x 12-1/4#.

Estimated weight of member (3-4).

2	Channels 7" x 12-1/4#	17'-0"	417
4	Batt.Pl.18"x3/8"x	2'-0"	184
1	Lac.Bar 2-1/2"x3/8"	40'-0"	128
			729
	Rivet Heads 2-1/2%		18
			747#

Estimated weight of member (5-6).

2	Channels 7" x 12-1/4#	30'-0"	735
	Details		330
			1066#

Estimated weight of member (7-8).

2	Channels 7" x 12-1/4#	40'-0"	980
	Details		330
			1310#

Estimated weight of member (9-10).

2	Channels 7" x 12-1/4#	48'-0"	1176
	Details		330
			1506#

Estimated weight of member (11-12).

2	Channels 7" x 12-1/4#	54'-6"	1335
	Details		330
			1665#

Members (4-5), (3-6), (6-7), (5-8), (7-10), (10-11), (9-12).

Stress = 15000#

Required area = 15000/10000 = 1.50 sq. ins.

Two angles 3-1/2"x3-1/2"x3/8" have a gross area of 4.96 sq. ins.

and a net area of 4.21 sq. ins.

Estimated weight of member (4-5) and (3-6)

2	Angles	3-1/2"x3-1/2"x3/8"x	40'-0"	680
3	Batt.pl.	18"x3/8"x	2'-0"	115
1	Lac.Bar	3"x3/8"x	56'-0"	215
				1010
		Rivet Heads 2-1/2%		25
		Weight of one piece =		1035#

Estimated weight of one member (6-7) and (5-8).

2	Angeles	3-1/2"x3-1/2"x3/8"x	47'-0"	799
3	Batt.Pl.	18"x3/8"x	2'-0"	115
1	Lac.Bar	3"x3/8"x	67'-0"	257
				1172
		Rivet Heads 2-1/2%		29
		Weight of one piece =		1201#

Estimated weight of members (7-10)and (8-9).

2	Angles	3-1/2"x3-1/2"x 3/8"x	50'-0"	850
3	Batt.pl.	18"x3/8"x	2'-0"	115
1	Lac. Bar.	3"x3/8"x	75'-0"	287
				1262
		Rivet Heads 2-1/2%		37
		Weight of one piece =		1299#

Estimated weight of (10-11 and (9-12).

2	Angles	3-1/2"x3-1/2" x3/8" x	55'-0"	935
3	Batt.Pl.	18"x3/8"x	2'-0"	115
1	LacBar.	3"x3/8"x	80'-0"	306
				1356
		Rivet Heads 2-1/2%		34
				1390#

Member DF or (4-6).

Stress = -406500#

If we assume the same section that is used in member (2-4), we find the required area to be 406500/6340 or 63.60 Sq. Ins. Since the same section is used the weight of DF is the same as the weight of BD.

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Member FH or (6-8).

Dead load on (6-8).

D.L. on (4-6)	55811
1/2 (5-6)	749
1/2 (EF)	1844
(6-7)	1201
FG	3353
	62558#
(4-6)	7146
	69704#

Stress = -478500#

Assume a section composed of:

4	Angles	6"x6"x3/4"	= 33.76 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	Plates	24"x3/8"	= 18.00 sq. ins.
	Total area		= 8176 sq. ins.

r = 5.84 P = 9000 - 2600 = 6400#

Required area = 478500/6400 = 74.76 sq. ins.

Estimated weight of member (6-8).

4	Angles	6"x6"x3/4"x	32'-0"	3674
2	Plates	24"x5/8"x	32'-0"	3264
2	Plates	24"x3/8"x	32'-0"	1958
				8896#

Member HJ or (8-10).

Stress in member = -499000#

Assume same section as is used in (6-8).

Required area = 499000/6400 = 77.97 sq.ins.

- - - - - - - - - - - - - - - -

Member (10-12) or JK.

Stress in member = -510500#

Required area = 510500/6400 = 79.76 sq. ins.

Use the same section for (10-12) as is used in (8-10).

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Members HI and IJ.

Stress = 0 Members composed of 2 channels 7"x12-1/4", laced.

Estimated weight of HI.

2	Channels 7" x 12-1/4#	30'-0"	750
1	Lac.Bar 2-1/2"x3/8"x	90'-0"	287
			1037
	Rivet Heads 2-1/2%		26
			1063#

Estimated weight of IJ.

2	Channels 7"x12-1/4#	19'-0"	475
1	Lac Bar. 2-1/2"x3/8"x	55'-0"	175
			650
	Rivet Heads 2-1/2%		16
			666#

- -

Hangers.

Hangers composed of 2 angles 3-1/2"x3-1/2"x3/8", laced.

Estimated weight of hanger.

2	Angles 3-1/2"x3-1/2"x3/8"x	15'-0"	255
	Lacing		150
			405
	Rivet Heads 2-1/2%		10
			415#

Estimated weight of Bent #1.

2	AC	14292
2	CE	14292
2	EG	17792
4	AB	14752
4	(1-2)	2650
2	(1-4)	1672
2	(3-6)	2070
2	(5-8)	2402
1/2	GK	2504
6	AD	20118
	Hangers	830
		93374#

Estimated weight of Bent #2.

2	BD	14292
2	DF	14292
2	HF	17792
2	HK	23054
4	AB	14752
1/2	GK	2504
6	(1-2)	5361
2	(1-4)	1672
2	(3-6)	2070
2	(5-8)	2402
2	(7-10)	2598
2	(912)	2780
6	BC	20118
1	HI	2226
1	IJ	1336
	Hangers	2490
		129739#

Towers #(3-4) -#(5-6 -#(7-8)- #(9-10) -#(11-12).

All sections used in these towers are the same as the corresponding sections in tower #(1-2), except as noted.

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Member HJ or (8-10).

Stress = -569000#

Required area = 569000/6400 = 88.90 sq. ins,

Use a section composed of

4	Angles	6"x6"x7/8"	= 38.96 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x1/2"	= 24.00 sq. ins,
	Total Area		= 92.96 sq. ins.

Estimated weight of member.

4	Angles	6"x6"x7/8"x	32'-0"	4237
2	Plates	24"x5/8"x	32'-0"	3264
2	"	24"x1/2"x	32'-0"	2611
				10112
	Rivet Heads 3%			303
				10415#

- -

Member JL or (10-12).

Stress = -648000#

Required area = 648000/6400 = 101.26 sq. ins.

Use a section somposed of

4	Angles	6"x6"x7/8"	= 38.96 sq. ins.
2	Plates	24"x6/8"	= 30.00 sq. ins.
2	"	24"x3/8"	= 18.00 sq. ins.
4	Bars	6"x5/8"	= 15.00 sq. ins.
	Total area		= 101.96 sq. ins.

Estimated weight of member.

4	Angles	6"x6"x7/8"x	32'-0"	4237
2	Plates	24"x5/8"x	32'-0"	3264
2	"	24"x3/8"x	32'-0"	1958
4	"	6"x5/8"x	32'-0"	1652
				11091
		Rivet Heads		333
				11424#

Estimate weight of one bent.

POSTS.

2	BD	14292	
2	DF	14292	
2	HF	17792	
2	HJ	20830	
2	JL	22848	
		90054	90054

Longitudinal Struts and Braces.

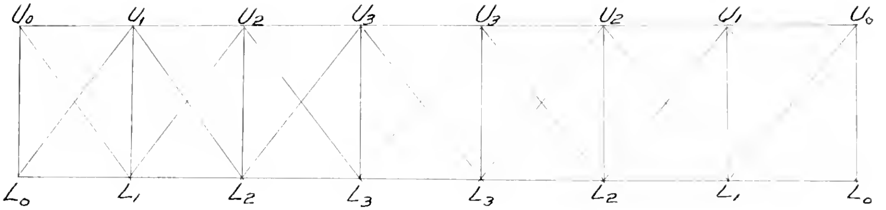
6	AB	23128	
10	BC	33530	
		56658	56658

Transverse Struts and Braces.

(1-2) (3-4) (5-6) (7-8) (9-10) (11-12).	5361	
(1-4) (2-3)	1672	
(3-6) (4-5)	2070	
(5-8) (6-7)	2402	
(7-10) (8-9)	2598	
(912) (10-11)	2780	
Hangers	1245	
	18128	18128
Weight of one bent	=	164840#

Weight of one tower = 2X 164840 = 329680#

DESIGN OF 145'-0" DECK SPAN.



Trusses are 21'-0" deep, and spaced 10'-0" apart.

Assume a dead load of 1250# per foot of truss.

CROSS TIES.

Assume that the ties are spaced 13" center to center.

The load per tie = 7900# . The cross tie then acts as a beam whose supports are 120" apart, and carrying two equal and symmetrically placed concentrated loads 59-1/2" apart, each of which is 7900#. Allowable unit stress, impact not considered, 1000# per sq. ins.

$M = 7900 \times 30 = 227000$"#.

$227000 = 1000bd2/6$

$Bd^2 = 1362$

If the safe bearing on the side of the fiber be taken at 250# per square inch, then the required area is

$7900/250 = 31.6$ sq. ins.

If the width of the base of rail is 6" then the breadth of the timber must be at least 6". We will use an 8" tie as it will give us a more economical dept of cross tie.

$d^2 = 1362/8 = 170$

$d^2 = 13.4$" or 14"

DEAD LOAD STRESSES.

Dead loa per panel = 1250 x20.714 = 25900#

Stress in U_3L_3 = -25900#

Stress in $U_2 L_2$ = -51800#

Stress in U_1L_1 = -77700#

Stress in U_0L_0 = -90650#

Stress in U_2L_3 = 25900 x 1.406 = 36415

Stress in U_1L_2 = 51800 x 1.406 = 72831#

Stress in U_0L_1 = 77700 x 1.406 = 109246#

Bending moment on center panel = 3258875 '#

Bending moment on U_1U_2 = 2680650 '#

Bending moment on U_0U_1 = 1608390'#

Stress in U_2U_2 = 3258875/21 = -155184#

Stress in L_3L_3 =3258875/21 = 155184#

Stress in U_1U_2 = 2680650/21 = 127650#

Stress in L_2L_3 = 2680650/21 = 127650#

Stress in U_0U_1 = 1608390/21 = -76590#

Stress in L_1L_2 = 1608390/21 = 76590

LIVE LOAD STRESSES.

Bending moment at U_1 = 4502405'#

Bending moment at U_2 = 7504371'#

Bending moment at U_3 = 9198438'#

Stress in U_2U_2 = -438020#

Stress in L_3L_3 = 438020#

Stress in U_1U_2 = 357295#

Stress in L_2L_3 = 357292#

Stress in U_0U_1 = -214400#

Stress in L_1L_2 = 214400#

Shear in panel U_2U_3 = 86540#

Shear in panel U_1U_2 = 136350#

Shear in panel U_0U_1 = 250960#

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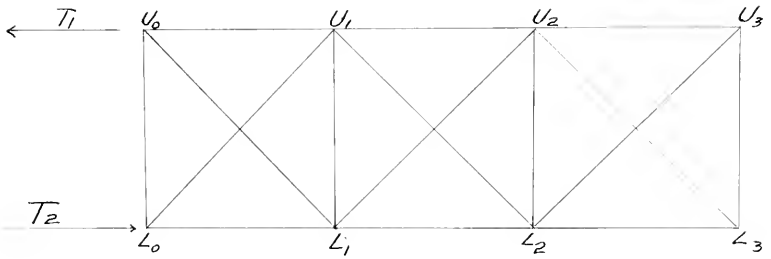
tresses due to cantilever ethod of erection.



T_2 = 25900(41.42 · 20.71 31.070/21 = -115000#

T_1 = 25900(41.42 20.71 31.07)/21 = 115000#

Stress in U_2U_3 = 0

Stress in U_1U_2 = 12900# = $-L_2L_3$

Stress in U_0U_1 = 51085# = $-L_1L_2$

Stress in L_0L_1 = 115000#

Stress in $U_{\cdot}L_3$ = 12900 x 1.406 = 18208#

Stress in U_1L_2 = 38850 x 1.406 = 54623#

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Stress due to traction on span.

Traction load on one panel = 20.714 x 3500 x.2 = 14500#

Stress in U_1U_0- U_1U_2- U_2U_3- U_3U_3= - 14500#

Stress in L_0L_1 = 14500 x 6 = 87000#

Stress in L_2L_3 = 14500 x 6 = 72500#

Stress in L_2L_3 = 14500 x 4 = 58000#

Stress in L_3L_3 = 14500 x 3 = 43500#

Stress in $U_1L_0-U_2L_1-U_3L_2-U_3L_3-U_2L_3-U_1L_2-U_0L_1=$

$= 14500 \times 1.423 = 20635\#$

tress in $U_0L_0-U_1L_1-U_2L_2-U_3L_3= 20635/1.406 = 14675\#$

Member	D. L.	L .L.	Traction	Erection	Max.
U_2U_2	-155184	-438020	-14500	12900	-530112
U_1U_2	- 55184	+438020	43500	-12900	530112
U_1U_2	-127650	-357295	-14500	51085	-435620
L_2L_3	127650	+357295	58000	-51085	479120
U_0U_1	-76590	-214400	-14500	115000	-267235
L_1L_2	76590	214400	72500	-115000	325195
U_2L_3	36415	101675	20635	18208	160517
U_1L_2	72830	191698	20635	54623	248748
U_0L_1	109246	357850	20635	91039	428108
U_3L_3	-25900	-72485	-14675	-12950	-100110
U_2L_2	-58100	-144970	-14675	-38850	-188695
U_1L_1	-77700	-217455	-14675	-64750	-270980
U_0L_0	-90650	-253750	-14675	-77700	-303750
U_3L_3	0	44850	20635		65485
L_0L_1	76590	214400	8700	-115000	239695

Member U_2U_2

$F = 10000 - 45L/r$ Assume $r = 5.6$

$F = 10000 - 1980 = 8120$

Required area $= 530112/8120 = 65.28$ sq. ins.

4 Angles 6"x6"x13/16" = 36.36 sq. ins.

2 Plates 24"x5/8" = 30.00 sq. ins.

Total area 66.36 sq. ins.

Member U_1U_2

Required area = 435620/8120 = 53.64 sq. ins,

4 Angles 6"x6"x9/16" = 25.72 sq. ins.

2 Plates 24"x5/8" = 30.00 sq. ins.
Total Area = 55.72 sq. ins.

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Memner U_0U_1

Required area = 267235/8100 = 32.92 sq. ins.

4 Angles 6"x6"x9/16" = 25.72 sq. ins.

2 Plates 24"x3/8" = 18.00 sq. ins.
Total Area = 43.72 sq. ins.

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Member L_3L_3

Required net area = 559112/10000 = 55.91 sq. ins.

4 Angles 6"x6"x3/4" = 33.76 sq. ins.

2 Plates 24"x9/16" = 27.00 sq. ins.
Total area = 60.76 sq. ins.

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Member L_2L_3

Required net area = 479120/10000 = 47.91 sq. ins.

4 Angles 6"x6"x5/8" = 28.44 sq. ins.

2 Plates 24"x9/16" = 27.00 sq. ins.
Total area = 55.44 sq. ins.

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Member L_1L_2

Required net area = 325195/10000 = 32.52 sq. ins.

4 Angles 6"x6"x1/2" = 23.00 sq. ins.

2 Plates 24"x3/8" = 18.00 sq. ins.
Total area = 41.00 sq. ins.

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Required net area of = 160517/10000 = 16.05 sq. ins.

2 channels 15" - 33# = 19.8 sq. ins.

Member U_1L_2

Required net area = 248748/10000 = 24.87 sq. ins.

2 Channels 15" -50# = 29.42 sq. ins.

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Member U_0U_1

Required net area = 428108/1000 = 42.81 sq. ins.

4 Angles 6"x4"x11/16" = 25.64 sq. ins.

" Plates 18"x3/4" = 27.00 sq. ins.
Total area = 52.64 sq. ins.

Net area of section = 52.64 - 8.75 = 43.89 sq. ins.

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Member L_0U_1, L_1U_2, L_2U_3

Section composed of 4 angles 6"x3-1/2"x1/2".

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Member U_3L_3

Required net area = 65485/10000 = 6.55 sq. ins.

Section composed of 4 angles 6"x3-1/2"x1/2".

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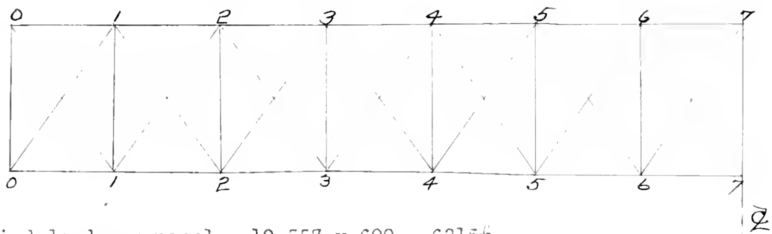
LATERAL SYSTEM.



Wind load per panel = 10.357 x 600 = 6215#

Stress in 7-7 = -3108#

Stress in 6-6 = -9323#

Stress in 5-5 = -15538#

Stress in 4-4 = -21753#

Stress in 3-3 = -27968#

Stress in 2-2 = -34185#

Stress in 1-1 = -40398#

Stress in 0-0 = -43506#

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Members 7-7 and 5-5.

Required area = 15538/6400 = 2.43 sq. ins.

Section composed of one angle 6"x4"x3/8".

- - - - - - - - - - - - - - - -

Members 3-3 and 1-1.

Required area = 40398/6400 = 6.31 sq. ins.

Section composed of one angle 6"x4"x11/16".

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Stress in 0-1 = 58800#

Stress in 1-2 = 46300#

Stress in 2-3 = 37800#

Stress in 3-4 = 29380#

Stress in 4-5 = 21100#

Stress in 5-6 = 12600#

Stress in 6-7 = 4220#

Area = 58800/18000 = 3.27 sq. ins.

One angle 6"x6"x3/8" has a net area of 3.61 sq. ins.

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INTERMEDIATE CROSS FRAME.

Stress in horizontal member = 34185

Stress in diagonal member = 38800

Horizontal member composed of 2 angles 5"x3-1/2"x3/8".

Diagonal member composed of one angle 4"x4"x3/8".

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END CROSS FRAME.

Horizontal member composed of two angles 5"x3-1/2"x1/2".

Diagonal member composed of one angle 5"x3-1/2"x9/16".

ESTIMATED WEIGHT OF 145' -0" DECK SPAN.

4	Angles	6"x6"x13/16"x	62'-2"	7710
8	Angles	6"x6"x9/16"x	41'-5"	7255
2	Plates	24"x5/8"x	103'- 7"	5467
4	"	24"x3/8"x	20'-8"	2488
1	"	24"x3/8"x	145'-0"	4437
4	Channels	15"x33#x	20'-0"	2640
4	"	15"x50#x	20'-0"	4000
16	Angles	6"x6"x9/16"x	20'-0"	7008
8	Plates	18"x3/8"x	20'-0"	3674
2	"	24"x9/16"x	62'-2"	5708
4	"	24"x3/8"x	41'-6"	5080
4	Angles	6"x6"x3/4"x	20'-8"	2333
8	"	6"x6"x5/8"x	20'-8"	4001
8	"	6"x6"x1/2"x	41'-6"	6507
8	"	6"x3-1/2"x1/2"x	29'-6"	3611
4	Channels	15"x33#x	29'-6"	3927
4	"	15"x50#x	29'-6"	5950
8	Angles	6"x4"x11/16"x	29'-6"	5188
4	Plates	18"x3/4"x	29'-6"	5414
24	Angles	6"x3-1/2"x1/2"x	29'-6"	10832
8	"	6"x4"x3/8"x	11'-0"	1082
8	"	6"x4"x11/16"x	11'-0"	1918
21	"	6"x6"x3/8"x	14'-6"	4527
12	"	5"x3-1/2"x3/8"x	11'-0"	1373
5	"	4"x4"x7/8"x	23'-6"	1591
4	"	5"x3-1/2"x1/2"x	11'-0"	599
2	"	5"x3-1/2"x9/16"x	23'-6"	719
				114901#
		Rivet Heads 3%		3447
				118348#

Weight of span = 2 x 118348 = 236696#

Towers #(13-14) and #(15-16).

Traction load on tower #(13-14) is 12 450#

Traction load on tower #(15-16) is 81200#

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Tower #(15-16).

Members AB - CD - EF - GH - IJ - KL.

Stress = -81200#

Required area = 81200/5425 = 14.94 sq. ins.

Owing to length of member we will use 2 channels 15"-33#.

Estimated weight of one member is 3688#.

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Members BC - AD - CF - DE - FG - EG.

Stress = 106000#

Required net area = 106000/12000 = 8.83 sq. ins.

Use 2 channels 12"-25#, laced.

Estimated weight of one member is 3353#.

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Member (1-2).

Stress = -111000#

Required area = 111000/7700 = 14.46 sq. ins.

Use 2 channels 10"-25#, laced.

Estimated weight of one member is 600#.

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Members (1-4) and (2-3).

Required net area = 63000/12000 = 5.25 sq. ins.

Use 2 angles 4"x4"x7/16".

Estimated weight of one member.

2	Angles	4"x4"x7/16"x	35'-0"	791
2	Batt.Pls.	18"x3/8"x	2'-0"	92
1	Lac Bar	2-1/2"x3/8"x	40'-0"	128
				1011
		Rivet Heads 3%		37
				1048#

Member (1-3) and (2-4).

Stress = -434000#

Assume a section composed of:

4	Angles	6"x6"x1/2"	= 23.00 sq. ins.
2	Plts.	24"x5/8"	= 30.00 sq. ins.
2	Plts.	24"x3/8"	= 18.00 sq. ins.
			71.00 sq. ins.

Required area = 434000/6400 = 67.81 sq. ins.

Estimated weight of one member.

4	Angles	6"x6"x1/2"x	32'-0"	2509
2	Plates	24"x5/8"x	32'-0"	3264
2	"	24"x3/8"x	32'-0"	1958
				7731#

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Members (3-5) and (4-6).

Stress = -593000#

Use same section as is used in member (6-8), tower #(3-4).

Weight of one piece is 8896#.

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Member (5-7) and 6-8).

Stress = -577000#

Assume a section composed of:

4	Angles	6"x6"x15/16"x	= 41.48 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x3/8"	= 18.00 sq. ins.
			89.48 sq. ins.

Required area = 577000/6500 = 88.77 sq. ins.

Estimated weight of one member.

4	Angles	6"x6"x15/16"x	32'-0"	4518
		Details		5222
				9740#

Member (7-9) and (8-10).

Stress = - 653000#

Use same section as is used in member (10-12), tower #(3-4).

Weight of one member is 11424#.

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Member (9-11) and (10-12).

Stress = - 725000#

Assume a section composed of:

4	Angles	6"x6"x15/16"	= 38.96 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x1/2"	= 24.00 sq. ins.
4	"	6"x1"	= 24.00 sq. ins.
			116.96 sq. ins.

Required area = 725000/6400 = 113.30 sq. ins.

Estimated weight of one member.

4	Angles	6"x6"x15/16"x	32'-0"	4518
2	Plates	24"x5/8"x	32'-0"	3264
2	"	24"x1/2"x	32'-0"	2611
4	"	6"x1"x	32'-0"	2611
				13004#

- -

Members (3-4), (4-5), (5-6), (6-7), (7-8), (8-9), (9-10), and (10-11)

Use same sections as are used in corresponding members in

Tower #(3-4).

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ESTIMATED WEIGHT OF ONE BENT.

Posts	101590
Longitudinal Struts abd Bracing	56658
Transverse Struts and Bracing	18552
	176800#

Weight of tower #(15-16) = 2 x 176800 = 353600#.

Tower #(13-14).
Member (1-3) and (2-4).

Stress = -477000#

Use the same section as is used in member (6-8), tower #(3-4).

Estimates weight of member is 8896#.

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Member (3-5) and ((4-6).

Stress = -589000#

Use same section as is used in member (6-8), tower #(15-16).

Estimated weight of member is 9740#.

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Members (5-7) and (6-8).

Stress = -706000#

Assume a section composed of:

4	Angles	6"x6"x15/16"	= 38.96 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x1/2"	= 24.00 sq. ins.
4	"	6"x3/4"	= 18.00 sq. ins.
			110.96 sq. ins.

Required area = 706000/6400 = 110.31 sq. ins.

Estimated weight of member.

4	Angles	6"x6"x15/16"x	32'-0"	4518
2	Plates	24"x5/8"x	32'-0"	3264
2	"	24"x1/2"x	32'-0"	2611
4	"	6"x3/4"x	32'-0"	1958
				12351#

Member (7-9) and (8-10).

Stress = - 2400#

Assume a section composed of

4	Angles	8"x8"x1"	= 60.00 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x1/2"	= 24.00 sq. ins.
			114.00 sq. ins.

Required area = 824000/7300 = 112.88 sq. ins.

Estimated weight of member.

4	Angles	8"x8"x1"x32'-0"	6528
2	Plates	24"x5/8"x32'-0"	3264
2	"	24"x1/2"x32'-0"	2611
			12403#

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Member (9-11) and (10-12).

Stress = -940000#

Assume a section composed of

4	Angles	8"x8"x1"	= 60.00 sq. ins.
2	Plates	24"x5/8"	= 30.00 sq. ins.
2	"	24"x1/2"	= 24.00 sq. ins.
4	"	8"x3/8"	= 12.00 sq. ins.
			126.00 sq. ins.

Required area = 940000/75000 = 125.33 sq. ins.

Estimated weight of member.

4	Angles	8"x8"x1"x32'-0"	6528
2	Plates	24"x5/8"x32'-0"	3274
2	"	24"x1/2"x32'-0"	2611
4	"	8"x3/8"x 32'-0"	1306
			13709#

Weight of Bent #14.

POSTS.

2 BD	17792	
2 DF	19480	
2 HF	24702	
2 HJ	24806	
2 JL	27418	
	114198	114198

Longitudinal Struts and Bracing.

6 BC	23128	
10 BC	33530	
	56658	56658

Transverse Struts and Bracing	18552
	189408#

Weight of tower #(13-14) = 2 x 189408 = 378816#

Bent #17.

Members (1-2), (3-4), and (5-6).

Stress = -24000#   Length = 20'-0"

Required area = 24000/6500 = 3.69 sq.ins.

Use a section composed of 2 channels 10"-20#.

Estimated weight of member.

(1-2)

2	Channels	10"-20# x 8'-0"	320
1	Lac.Bar	$2\frac{1}{2}$"x3/8"x23'o"	74
4	Plates	18"x3/8"x2'-0"	152
			546
		Rivet Heads 3%	16
			562#

(3-4)

2	Channels	10"-20# x 14'-0"	560
1	Lac.Bar	$2\frac{1}{2}$"x3/8"x 40'-0"	128
4	Plates	18"x3/8"x 2'-0"	152
			840
		Rivet Heads 3%	25"
			865#

(5-6)

2	Channels	10"-20# x 20'-0"	800
1	Lac.Bar	$2\frac{1}{2}$"x3/8"x 55'-0"	176
4	Plates	18"x3/8"x 2'-0"	152
			1128
		Rivet Heads 3%	34
			1162#

Member (2-4).

Stress = -240000#

Required area = 240000/7300 = 32.70 sq.ins.

Use section composed of 2 channels 15"-55#.

Estimated weight of member.

2	Channels	15"-55# x 19'-0"	2090
1	Lac.Bar	3"x3/8"x 55'-0"	209
4	Plates	18"x3/8"x 2'-0"	152
			2451
		Rivet Heads 3%	74
			2525#

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Member (4-6).

Stress = -241000#

Use same section as is used in member (2-4), tower #(17).

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Members (2-3) and (4-5).

Stress = 30000#

Net area required = 30000/10000 = 3.00 sq.ins.

Use section composed of 2 angles $3\frac{1}{2}$"x$3\frac{1}{2}$"x3/8".

Estimated weight of member.

2	Angles	$3\frac{1}{2}$"x$3\frac{1}{2}$"x3/8"x23'-0"		391
1	Lac.Bar	3"x3/8"x	30'-0"	114
4	Plates	12"x3/8"x	1'-3"	77
				582
		Rivet Heads 3%		18
				600#

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Estimated weight of Bent #17.

1	(1-2)	562
1	(3-4)	865
1	(5-6)	1162
4	(2-4)	10100
4	(2-3)	2400
		15089#

Pequired bearing area for different bents.

Bent #1 = 478500/250 = 1914 sq.ins. = 44"x44"

Bent #2 = 510500/250 = 2042 sq.ins. = 45"x46"

Bents #3-4-5-6-7-8-9-10-11-12 = 648000/250 = 2592 sq.ins. =

= 51"x51"

Bents #13-14 = 940000/250 = 3760 sq.ins. = 62"x61"

Bents #15-16 = 725000/250 = 3000 sq.ins. = 55"x55"

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Concrete in pier #1	= 2 x 594 =	1188 cu.ft.	
" " " #2	= 2 x 436 =	872 cu.ft.	
" " " #3	= 2 x 434 =	868 cu.ft.	
" " " #4	= 2 x 541 =	1082 cu.ft.	
" " " #5	= 2 x 383 =	766 cu.ft.	
" " " #6	= 2 x 459 =	918 cu.ft.	
" " " #7	= 2 x 601 =	1202 cu.ft.	
" " " #8	= 2 x 788 =	1576 cu.ft.	
" " " #9	= 2 x 969 =	1938 cu.ft.	
" " " #10	= 2 x 1060=	2120 cu.ft.	
" " " #11	= 2 x 1412=	2824 cu.ft.	
" " " #12	= 2 x 1522=	3044 cu.ft.	
" " " #13	= 2 x 2025=	4050 cu.ft.	
" " " #14	= 2 x 8371=	16742 cu.ft.	
" " " #15	= 2 x 7928=	15856 cu.ft.	
" " " #16	= 2 x 1485=	2970 cu.ft.	
" " " #17	= 2 x 774 =	1548 cu.ft.	
Total volume	=	59564 cu.ft.	=
	=	2206 cu.yds.	

Estimated weight of structure.

8	77'-6" Girders	341144
9	38'-6" Girders	154908
Tower #(1-2)		269922
Towers #(3-4),(5-6),(7-8),(9-10),(11-12)		1648400
Tower #(13-14)		378816
Tower #(15-16)		353600
Tower #17		15089
1	145'-0" Span	236696
		3498575#

Estimated cost.

1750 tons steel @ $85	$148750
2206 cu.yds. concrete @ $5.20	$ 11475
Total cost	$160225

SPECIFICATIONS FOR PORTLAND CEMENT.

1. PACKAGES. Cement shall be packed in strong cloth or canvas sacks. Each package shall have printed upon it the brand and name of the manufacturer. Packages received in broken or damaged condition may be rejected or accepted as fractional packages.

2. WEIGHT. Four bags shall constitute a barrel, and the average net weight of the cement contained in one bag shall be not less than 94 lbs. or 376 lbs, net per barrel. A cement bag may be assumed to weigh one pound. The weights of the separate packages shall be uniform.

3. REQUIREMENTS. Cement failing to meet the seven-day requirements may be held awaiting the result of the twenty-eight-day tests before rejection.

4. TESTS. All tests shall be made in accordance with the methods proposed by the committee on Uniform Tests of Cement of the American Society of Civil Engineers, present to the Society January 21, 1903, and amended January 20, 1904, with all subsquent amendments thereto.

5. SAMPLING. Samples shall be taken at random from sound packages, and the cement from each package shall be tested separately.

6. The acceptance or rejection shall be based on the following requirements.

7. DEFINITION OF PORTLAND CEMENT. This term is applied to the finely pulverized product resulting from the calcinationto incipient fusion ot an intimate mixture of properly

proportioned argillaceous and calcareous materials, and to which no addition greater than 3% has been made subsequent to calcination.

8. SPECIFIC GRAVITY. The specific gravity of the cement, thoroughly dried at 100 Cent., shall be not less than 3.10.

9. FINENESS. It shell leave by weight a residue of not more then 8% on the No 100, and not more than 25% on the No. 200 sieve.

10. TIME OF SETTING. It shell develope initial set in not less than thirty minutes, but must develope hard set in not less than one hour nor more than then hours.

11. TENSILE STRENGTH. Briquettes one inch square in section shall attain at least the following tensile strengths and shall show no retrogression within the periods specified.

Neat Cement .

Age	Strength.
24 hours in moist air	175#
7 days (1day in air, 6days in water)	500#
28 days (1" " " , 27 " " ")	600#

One Part Cement, Three Parts Standard Sand.

Age	Strength.
7 days (1day in air, 6 days in water)	150#
28 days(1 " " ",27 " " ")	200#

12 SOUNDNESS OR CONSTANCY OF VOLUME. Pats of neat cement about three inches in diameter, one-half inch think at the center, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature, and

observed at intervals for at least 28 days.

(b) Another pat is kept in water maintained as near 70F. as practicable, and observed at intervals for at least 28 days

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above aboiling water, in a loosely closed vessel for five hours .

These pats to satisfactorily pass the requirements shall remain firm and hard and show no signs to distortion, checking, cracking or disintegration.

13. SULPHURIC ACID AND MAGNESIA. The cement shall not contain more than 175% of anhydrous sulphuric acid (SO_3(, not more than 4% of Magnesia (MgO).

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SPECIFICATIONS FOR PORTLAND CEMENT.

1 Cement. The cement shall be first-class Portland cement of reputable brand which shall conform inall respects to the cement specifications herewith annexed. The cement shall be stored in a building which will protect it from the weather. The floor upon which the cement is placed shall be at least 6" above the ground. It shall be stored so as to permit of easy access for inspection and indentification of each shipment. A sufficient quantity shall be kept on hand at all times so that the Engineer may have opportunity and time to make tests sufficient to determine its quality. At least 12 days shall be allowed for inspection and necessary tests.

2. SAND. The sand shall be clean and coarse, or a mixture of course and fine grains with the coarse grains predominating

it shall be free from clay, loam, sticks, organic matter, and other impurities.

3. SCREENINGS. Screenings or crusher dust from broken stone,- in which term is included all parricles passing a 1/4-inch screen, -may, by slightly altering the proportions of the ingredients, be substituted for the whole or a portion of the sand in such proportions as to give a dense mixture and the same relative volumes of total aggregate.

4. GRAVEL. The gravel shall be composed of clean pebbles free from sticks and other foreign matter and containing no clay ot other material adhering to the pebbles in such quantity that it cannot be lightly brushed off with the hand or removed by dipping in water. It shall be screened to remove the sand, which be afterwards be remixed with it in the required proportions.

5. BROKEN STONE. The broken or crushed stone shall consist of pieces of hard and durable rock, such as trap, linestone, granite, or conglomerate. The dust shall be removed by a 1/4-inch screen, to be afterwards, if desired, mixed with and used as a part of the sand, except that ifthe product of the crushed is delivered to t e mixer so regularly that thw amount of dust, as determined by frequently screening samples, is uniform, the screenings may be omitted and the average percentage of dust allowed for in measuring the sand.

6. WATER . The ater shall be free from acids or strong alkalies.

7 PROPORTIONS. The proportions of the raw materials for the concrete shall be exactly determined from ime to time by the Engineer in ac ordance with the relative coarseness of the aggregat , so as to attain as dense a concrete as is consistend with the terms of the specifications which follow.

For all piers and abutments the concrete shall be a 1:3:6 mixture, or, one barrel (376 lbs.) cement to 11.4 cubic feet sand to 22.8 cubic feet broken stone, the cement to be measured as packed by the manufacturer, and the sane and other aggregate to be measured as shoveled loosely into an ordinary sand or stone measuring box or barrel.

8. HAND MIX NG. If the concrete is mixed by hand, the cement and aggregate shall be mixed and the water added on a tight platform large enou h to rpovide space for the partially simultaneous mixing of two batches of not more than one cubic yard each. The sand and cement shall be spread in thin layers and mixed dry until of uniform color. This mixture may be spread upon the layer of stone or the stone shoveled upon it before adding the water, or it may be made into a mortar. before sprwading it with the stone. In the former method the material shall be turned at least three times,- in addition to the mixing of the sane and cement already mentioned, the water being added on the first turning,- and in addition to the shoveling from the platform to place or into the vehicle for transportion, In the latter method, that is, if the sand and cement are first made into mortar,the mass of stone and mortar shall be turned at least twice. Whatever method

is employed, the number of turnings shall be sufficient to produce a resulting loose concrete of uniform color and appearance, with the stones thoroughly incorporated into the mortar and consistency uniform throughout.

9. MACHINE MIXING. If the concrete is mixed in a machine ixer a machine shall b selected into which the materials, including the water, can be precisely and regularly proportioned, and which will produce a concrete of uniform consistency and color with the stones and water thoroughly mixed and incorporated with the mortar.

10 CONSISTENCY. A mediu or quaking mixture of a tenacious, jelly-like consistency, which quakes on ramming, shall be used for all mass construction.

11 PLACING. Concrete shall be conveyed to place in such a manner that there shall be no sictinct separation of the ifferent ingredients , or, in cases where such separation in inadvertently occurs, the concrete shall be remixxed before placing. Each layer in which the concreteis placed shall be of such thickness that it can incorporated with the one prevesely layed. Concrete shall be used so soon after mixing that it can rammed or puddled in placed as a plastic bomogeneous mass . Any which has been set before placing shall be rejected. hen placing fresh concrete upon an old concrete surface, the latter shall be cleaned of all dirt and scum or laitance, and thoroughly wet. Noticeable voids or stone pockets discovered when the forms are removed shall be immediately filled with mortar mixed with the same proportion.

as the mortar in the concrete.

12. Ordinary Surface. Surfaces shall have no special treatment further than care in placing the concrete to avoid noticeable voids or stone pockets? Form shall be wet before placing concrete against them.

13 EXPOSED FACES. Faces exposed to view shall be made smooth by thrusting a spade or chisel through the concrete close to the form to force back the stone and prevent stone"pockets". The form shall be greased with crude oil before placing the concrete against them

14 FREEZING WEATHER. No concrete shall be exposed to frost until hard and dry. Materials employed in freezing weather shall contain to frost. Surfaces shall be protected from frost. Portions of surface concrete which have frozen shall be removed before laying fresh concrete upon them.

15 FORMS. The lumber for the forms and design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For Exposed faces the surface next to the concrete shall be dressed. Forms shall be sufficiently tight to prevent loss of cement or mortar. They shall be thoroughly braced or tied together so that the pressure of the concrete, or the movement of men, machinery, or materials, shall not throw them out of place. Forms shall be left in place until, in the judgement of the Engineer, the concrete has attained sufficient strength to resist accidental thrusts and premanent strains which may come [illegible]. Forms shall be thoroughly cleaned before being used again.

16. GENERAL REQUIREMENTS. Imperfect work or materials or work or materials which may become damaged from any cause before its acceptance, shall be properly replaced to the satisfaction of the Engineer.

Foremen employed by the contractor shall be skilled in concrete mixing, and they shall receive and obey orders from the Engineer.

No claims for extra work shall be allowed unless made in writing previous to its performance and signed by both parties or by their authorized representatives.

In case of disagreement as to the meaning ot the terms of the contracts or as to the manner of its execution, one arbitrator shall be appointed by each party within a week after notifications in writing by either party, and in case these cannot agree, a third arbitrator shall be selected by these two, and the decision of the majority of the arbitrators shall be final and binding on both parties.